INVESTIGATION OF SHOCK/ACCELERATION LOADS ON CARBON FILTERS DURING TRANSPORTATION AND HANDLING

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Abstract

This investigation was the second phase of an Army-sponsored two-phase effort to establish reasonable G-force requirements for industrial-type carbon filters. In the first phase, multidirectional shock/acceleration measurements were taken during production. Investigators found shock/acceleration forces on 24" x 24" x 16" v-bed cells to be about 50 G's using one manufacturer's standard production procedures. Based on these findings, the Army established a tentative 20 G multi-directional G-force production minimum shaking requirement for these particular filters. Present industrial specifications require cyclical shaking at 200 cpm and 3/4" fall onto a rigid metal plate: No G-force criterion is set. Owing to differences in weight and resiliency of colliding bodies, G-force levels experienced by different types of filters can vary widely.

The second phase identified a likely range of G forces experienced by the same type filters during transportation and handling. The purpose was to assess the reasonableness of the Army's tentative 20 G production-shaking requirement in view of the shock levels these filters are likely to experience after leaving the factory.

Investigators placed four shock-indicating devices in each of the 14 filter cells (total of 56 devices) shipped by truck to four sites in the U.S. Two of the four devices in each cell were calibrated to trip under a 10 G impact load and two were calibrated to trip under a 20 G impact load. Only one of the 56 devices tripped, a 10 G device. On the basis of this limited test, one can infer that the 20 G tentative production shaking requirement appears reasonable. Investigators discuss methods used to obtain these findings, the use of such findings in formulating *performance* requirements (vice *design* requirements), and possible need for industry-wide G force standards.

Objective
Under Contract Number DAAM01-96-D-0009, DO 4-57, SAIC was tasked by the U.S. Army to perform the second phase of an engineering investigation of the shock loads on carbon filter cells used with the mobile igloo filter systems. The focus of this investigation was to: (1) determine the shock loads on the filters during transportation and handling, and (2) recommend any changes to the procurement specification as a result of the investigation. To accomplish this task, SAIC placed shock overload indicator devices inside filter cells that were shipped to four Army sites. This report will describe the filter testing.

Background
Under Contract Number DAA15-91-D-0005, DO 186, SAIC was tasked to design, procure, and deliver seven prototype igloo filter systems. SAIC developed Igloo Filter Procurement Specification Number 4980-001 that identified the performance requirements for this transportable filter system. SAIC supplied seven filter systems to the U.S. Army through its subcontractor, Flanders/CSC. During the development of the igloo filter system, SAIC determined that the shock loads a filter cell would experience during transportation and handling will be about 3 Gs simultaneously in the horizontal and vertical directions. This 3 G shock load was tentatively posited in the procurement specification.

Under Contract Number DAAM01-96-D-0009, DO 4-13, SAIC was tasked to perform fragility testing of the filter cell during the manufacturing process. The testing was performed at the Flanders/CSC facility in December 1997. For this test, production-type equipment, carbon filters, and procedures were used. A rough handling machine was used to shake the filter cells after they were filled with carbon. This machine raised and dropped a tabletop at a rate of 200 cycles per minute. Since the filter cell sat on the tabletop, the cyclic motion of the tabletop transferred shock loads to the filter cell. Shock loads were measured using a 0 to 50 G accelerometer connected to a computer-based data acquisition system. The accelerometer was mounted in various positions on the filter cell to measure vertical and lateral shocks. Shock indicator devices rated at 3, 10, and 40 Gs were also used to measure shock. Initially, the accelerometer and shock devices were used to measure the shock produced only by the rough handling machine. Figure 1 shows the initial test setup. Subsequent testing involved measuring shocks for empty filter cells, and cells filled 25, 50, 75, and 100 percent full of carbon.

The testing provided three results. First, the filter cells experienced 50 or more Gs of acceleration simultaneously in the vertical and horizontal directions during the filling process. Figures 2 and 3 show typical shock curves from this test. Second, there was a good correlation between the accelerometer and the shock indicating devices. Third, there was a need for additional testing to measure the shocks on the filter cell during transportation and handling.

The results of this testing are contained in SAIC's *Igloo Filter System Filter Cell Fragility Test Report* dated February 1998. Based upon this fragility testing, SAIC determined that the 3 G shock loads identified in the igloo filter procurement specification were too low for the filter cell. SAIC determined that 20 Gs is a more reasonable level and is certainly achievable by filter manufacturers. On SAIC's recommendation, the Army adopted a 20 G simultaneous horizontal and vertical specification. Under DO 4-57, SAIC was tasked to verify the reasonableness of the 20 G shock value during filter cell transportation and handling.

Transportation and handling shock may occur at any one of three sources. The first shock source is at the manufacturing facility where the filter cell is manually lifted and packed into the shipping box. Also, shock loads may occur when a manufacturer's forklift moves a filter cell pallet and loads it onto a tractor-trailer. The second shock source may occur when the trailer truck transports the filter cell from the vendor facility to the Army site. The third shock source is at the Army site where the filter cell pallet is removed from the tractor-trailer using a forklift, transported by a flatbed truck, unloaded by forklift, and manually lifted out of the shipping box.

A low cost method of checking shock load, and the method used for the second phase of tests, was the use of shock overload indicator devices. The shock devices provide a visual indication when the rated shock value for the device has been exceeded. There is a clear plastic dome with a central bar and spring mechanism inside. To arm the device, a rod is inserted inside the dome to compress and latch the spring. When the device experiences a shock higher than the rated shock value, the spring has released and a red bar becomes visible, which indicates that the device has tripped. Figures 4 and 5 show the shock devices in the armed and tripped conditions, respectively.

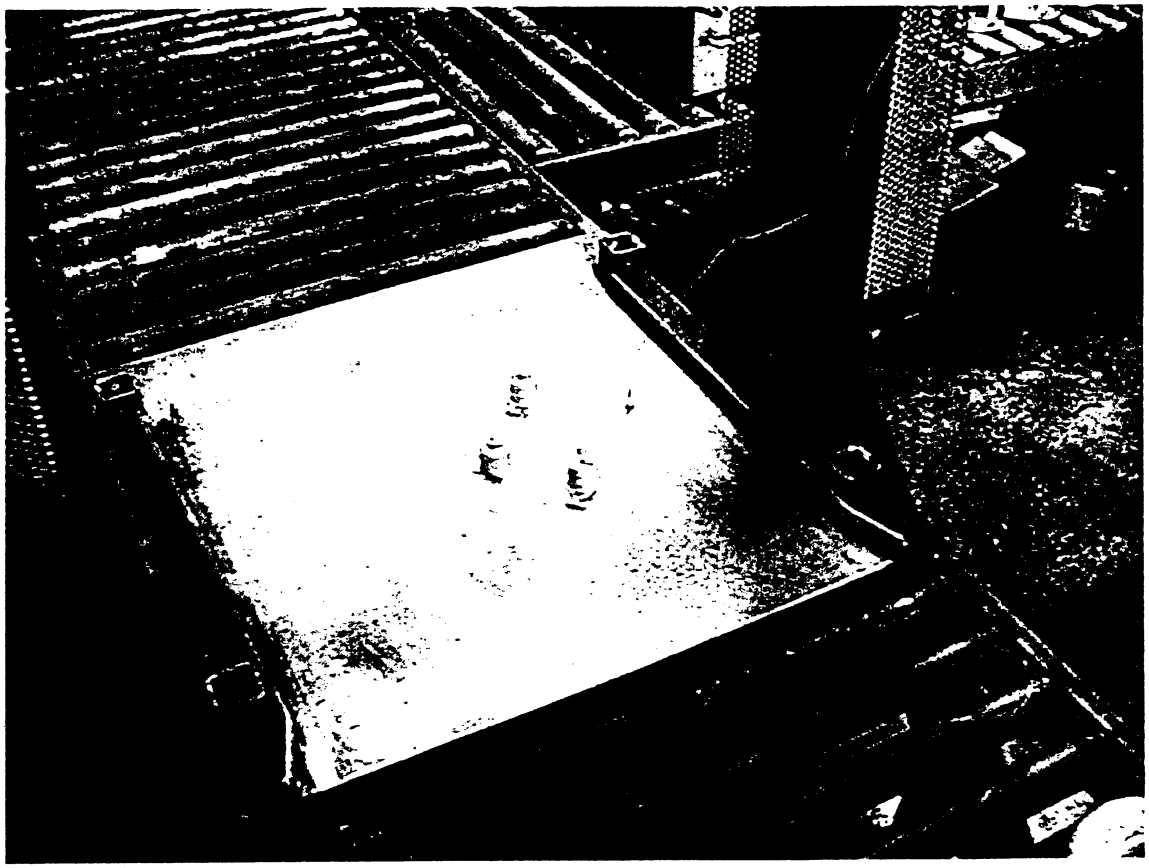

Figure 1. Test Setup for Rough Handling Machine

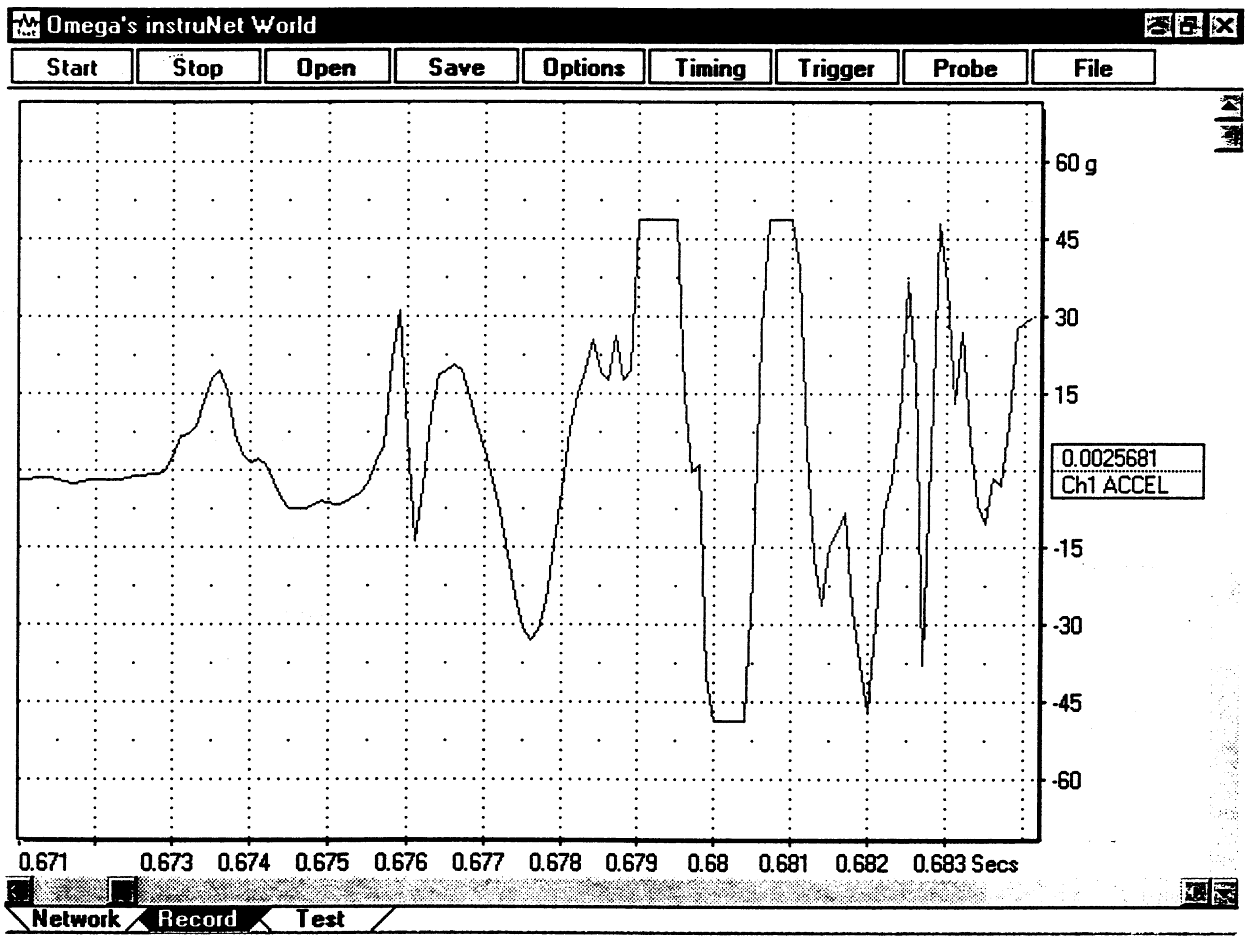

Figure 2. Vertical Acceleration of a 100-Percent Filled Cell

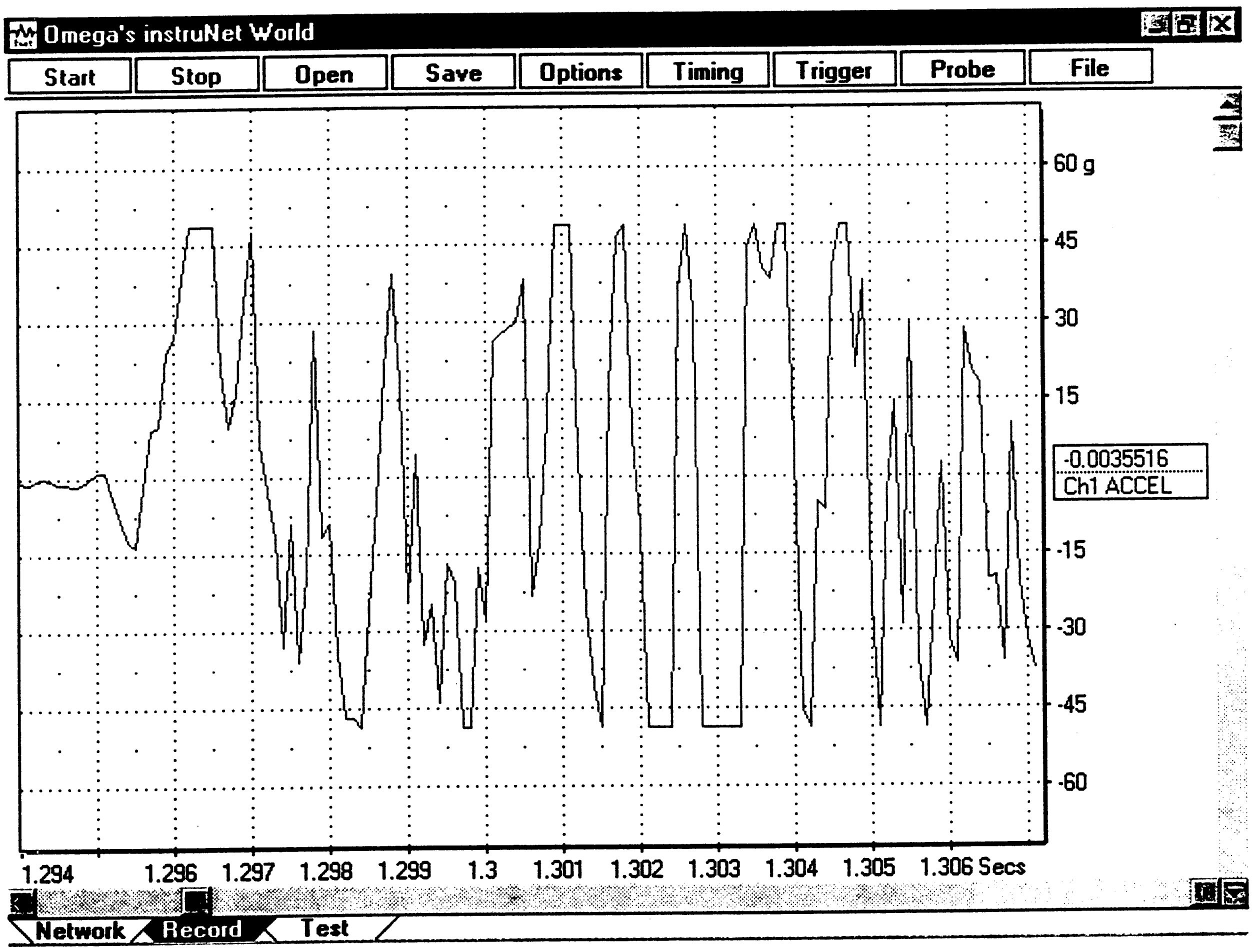

Figure 3. Lateral Acceleration of a 100-Percent Filled Cell

Phase 2 Tests

Test Location
The shock devices were installed in the filter cells at the Flanders/CSC facilities located in Bath, North Carolina. The final destinations of the filter cells with shock devices were the Army sites at Anniston, Alabama; Richmond, Kentucky; Edgewood, Maryland; and Hermiston, Oregon.

Test Schedule
The shock devices were installed in the filter cells on March 8, 2000 and shipped on March 10, 2000. Upon arrival, the filter cells were opened and shock devices were observed as follows: March 14 by Anniston, March 16 by Edgewood, March 22 by Umatilla, and April 4 by Blue Grass.

Equipment
Both 10 G and 20 G shock overload indicator devices were used for this test manufactured by AGM Container Controls, Inc. The model numbers were TA280-018-010 (10 G) and TA280-018-020 (20 G). The 14 filter cells procured under DO 4-57 were used for this test. The filter cells are Flanders/CSC model number CSC-16-62-AS.

Test Procedure
Each filter cell had four shock devices (two 10 G and two 20 G) mounted inside the filter bed. Prior to installation, each shock device was armed. The shock devices were mounted to sense shock in all directions. To accomplish this, one shock device of each type was mounted perpendicular to the other one. The four armed devices were mounted in the same filter cell row. Duct tape was used to secure the devices to the filter cell. Packing material was placed behind the devices to prevent them from falling into the filter cell. A second piece of duct tape was placed in front of the devices to prevent them from falling out of the filter cell. The packing material and tape were used in such a way as to prevent the shock devices from chattering, while keeping the shock devices in intimate contact with the cells. Figure 6 shows the shock devices installed inside the filter cell.

The filter cell with shock devices was sealed inside a plastic bag and placed inside a cardboard box. The box was sealed shut. The two carbon filter cell boxes were placed on a wooden pallet and secured to the pallet with plastic shrink wrap. When the filter system was shipped, the mobile filter was loaded onto a flatbed trailer. A forklift was used to load the filter cell pallet onto the truck. Both the filter system and pallet were secured to the trailer with tarps and ratchet straps.

The filter systems were shipped to the Anniston Chemical Activity in Anniston, Alabama; Blue Grass Chemical Activity in Richmond, Kentucky; Aberdeen Proving Ground in Edgewood, Maryland; and Umatilla Chemical Depot in Hermiston, Oregon. The trailer trucks traveled via a combination of state roads and interstate highways to deliver the filter systems to the Army sites. Upon arrival, forklifts were used to remove the filter cell pallets from the trailers. Forklifts were then used to load the filter cell pallets onto flatbed trucks, which delivered the pallets to their final destinations where they were off-loaded by forklifts. To examine the filter cell, the shrink wrap was cut from the pallet. The filter cell box was opened, and each filter cell was manually lifted and removed from the box. The plastic bag around the filter was opened to expose the shock devices inside. The shock devices were then observed in place. When the observations were completed, the shock devices, packing material, and duct tape were removed from the filter cell.

In order to capture the results from this investigation, observation instructions and a data sheet were prepared. The instructions and data sheet were forwarded to the Army sites. Site personnel observed the status of the shock device, filled in the data sheet, and returned both the shock devices and completed data sheets to SAIC.

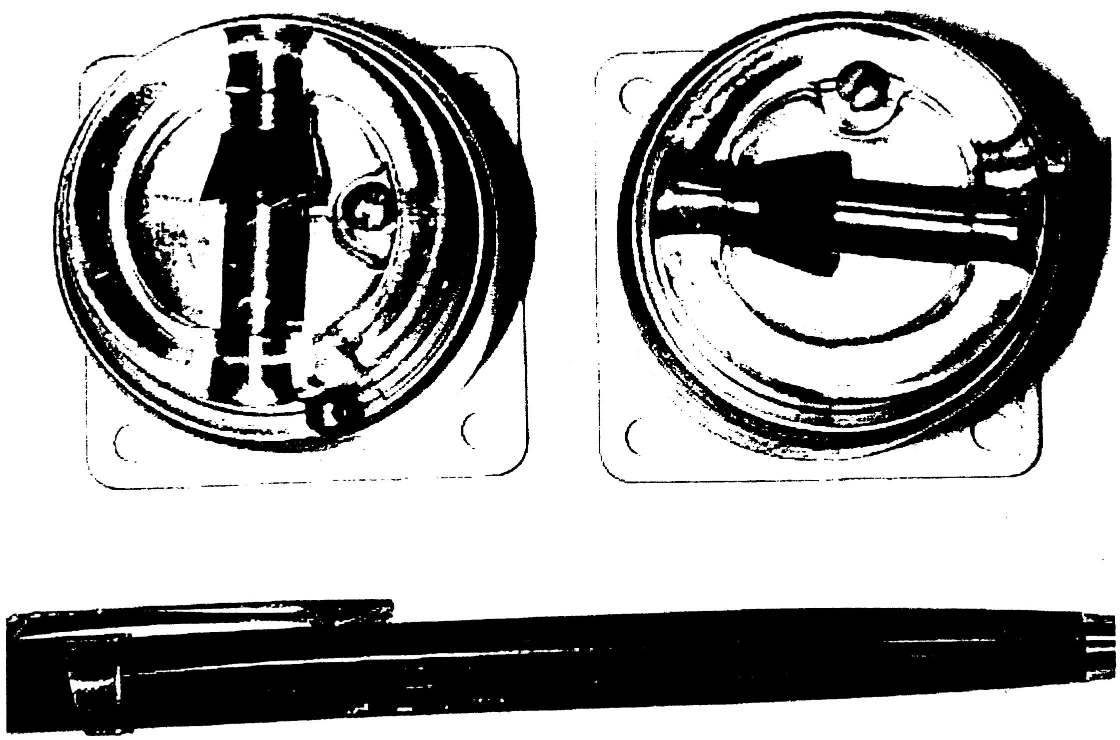

Figure 4. Shock Devices in the Armed Condition

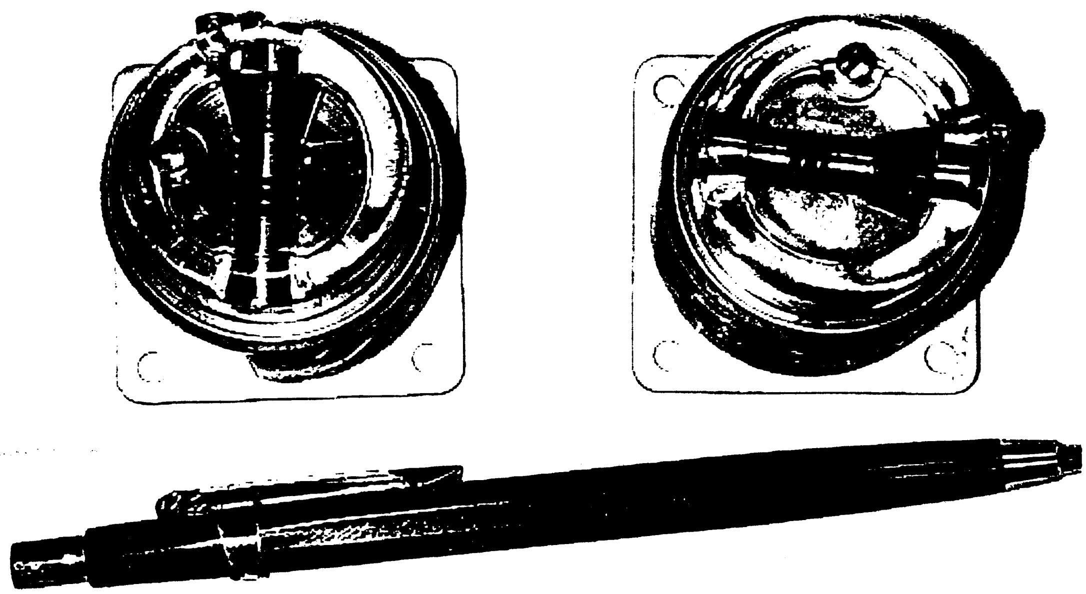

Figure 5. Shock Devices in the Tripped Condition

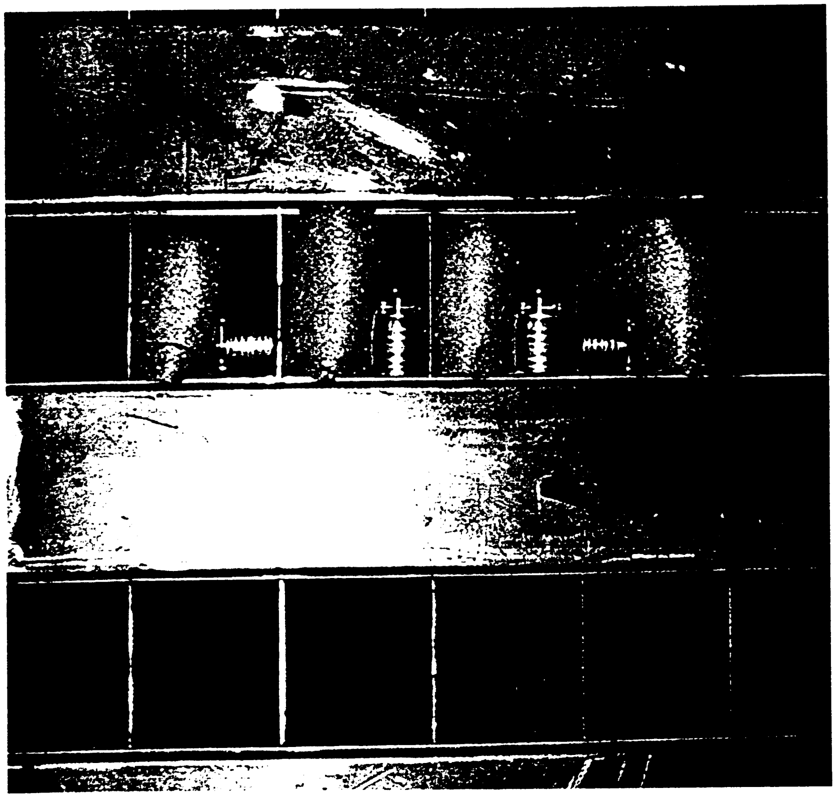

Figure 6. Shock Devices Mounted Inside the Filter Cell

Test Results
The test was performed to determine the relative magnitude of the shock loads on filter cells from the time the filter cells left the manufacturer's facility until the filters were received by the end users at the Army sites and to compare these results against production specification requirements. The transportation and handling shock loads were measured using shock overload indicator devices. Investigators determined that shock loads can occur at any of three points: (1) during handling at the manufacturer's facility, (2) during transportation to the Army sites, and (3) during handling and transportation at the Army sites. Filter cell packaging is important since it serves to mitigate shock loads.

Handling loads may have occurred both at the manufacturer's facility and at the Army sites. One type of handling involved lifting the filter cells by workers. Unless the filters were dropped, negligible shock loads should have occurred. A second handling involved the movement of the filter cell pallet by forklift. Negligible shock should have occurred unless the pallet was dropped rapidly onto a hard surface or the forklift rammed into the pallet. Driving the forklift over rough surfaces or surface transitions may have subjected the load to shocks within the range analyzed.

The *transportation* shock loads may have occurred by the long distance trailer trucks and/or the Army trucks. Both tractor trailers and flatbed trucks have shock absorbers and springs that mitigate most normal road-induced shock loads. The tractor trailer trucks used a combination of state roads and interstate highways to deliver the filter systems to the Army sites. The Army trucks most likely used paved roads. In both cases, any road shocks were probably relatively minor. Major shock loads may have occurred when the trailer or truck ran over a curb, hit a severe pothole in the road, ran over an object in the road, or backed into a loading dock. When the pallets are secured to the bed of the vehicle, transportation shock is unlikely to induce 10 to 20 Gs.

Since each filter cell weighed approximately 200 pounds, adequate packaging was essential to protect the filter cell. The manufacturer's standard practice involved sealing the filter cell in a plastic bag, installing the bagged filter cell inside a cardboard box, and sealing the box with tape. Two boxed filter cells then were placed on a wooden pallet. The boxes were secured to the pallets with shrink-wrapped plastic. The wooden pallets were loaded onto the trailer and secured in place with tarps and ratchet straps.

The shock loads were measured using shock overload indicator devices that provide a go/no-go visual indication that a specific shock level has been exceeded. In the active mode, a red bar in the shock device is hidden. When the device experiences a shock in excess of its rated value, the red bar becomes visible, and the device is tripped. The red bar may be removed only by manually resetting the device. The shock required to trip the device must be an impulse type of shock that may result from dropping the device onto a hard surface or from a forced cyclic movement.

For this test, shock devices with 10 G and 20 G trip setpoints were used. Each filter cell had two 10 G and two 20 G shock devices. One set of 10 G and 20 G shock devices was mounted perpendicular to the filter bed opening to measure vertical shock loads. The other set of 10 G and 20 G shock devices was mounted parallel to the filter bed opening (perpendicular to the first set of shock devices) to measure horizontal shock loads. This arrangement of shock devices permitted shock to be measured in all possible directions. For this test, 28 each of 10 G and 28 each of 20 G shock devices were used in the 14 filter cells.

The results from the visual observations are summarized in table 1. Anniston, Edgewood, and Umatilla reported that all 24 of their 10 G and 24 of their 20 G shock devices were active when observed. This result indicates that none of the 12 filter cells experienced a 10 G or greater shock load. Blue Grass reported that one of the four 10 G shock devices had tripped. The other three 10 G and four 20 G devices were active. This result indicates that one of the two filter cells experienced a shock load between 10 and 20 Gs. The one 10 G device that was tripped was mounted to sense shock in the horizontal plane. It is most likely that this device was tripped during handling operations by forklift loading or unloading the filter cell pallet on or off of a truck.

Table 1. Summary of Test Results

Army Site	Shipping Distance – Miles	Number of Filters	Number of Shock Devices		Status of Shock Devices	
			10 G	20 G	Active 10 G	Active 20 G
Anniston	579	6	12	12	12	12
Blue Grass	566	2	4	4	3	4
Edgewood	343	2	4	4	4	4
Umatilla	2,762	4	8	8	8	8
Total	4,250	14	28	28	27	28

This test indicated that all 56 shock devices experienced less than 20 Gs during the shipping and handling process. In addition, 55 of the 56 shock devices experienced less than 10 Gs from the time the filter cells were packaged by the manufacturer until Army personnel opened them up. There are two possible explanations for this result.

First, the filter cell pallets were not exposed to impact shock loads of 10 Gs or greater during this test. Second, the filter cell pallets were exposed to high shock loads, but the filter cell packaging helped to mitigate the shock below the 10 G setpoint value for the shock devices. When the shock devices were returned to SAIC, they were examined and determined to be in good working condition. All the shock devices returned to SAIC were tripped despite being packaged in cushioned boxes. The tripped condition indicates that the shock devices received shock loads higher than their setpoint values on their return trips from the Army sites. These shock loads probably occurred when the boxes were loaded and removed from the delivery trucks and/or by the shock devices striking each other.

Conclusions

Shock loads of less than 10 Gs were experienced by 55 of the 56 shock devices.

One filter cell was exposed to a shock load that was greater than 10 Gs, but less than 20 Gs.

The 20 G shock value currently identified in the mobile filter system procurement specification is considered reasonable and should not be changed.

The manufacturer's standard packing box and pallet system is an acceptable means of protecting the filter cells.

Tractor-trailers are an acceptable method of transporting the filter cells.

Buyers should specify G-force requirements consistent with the expected shock loads.

References

Science Applications International Corporation, *Igloo Filter System Filter Cell Fragility Test Report*, February 1998

Aronyms/Abbreviations

DO	delivery order
G	acceleration (due to gravity)
SAIC	Science Applications International Corporation